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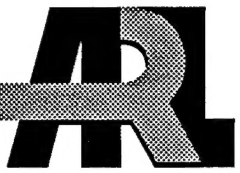

The MAVEN Approximation Method Within the MUVES Environment

Mark D. Burdeshaw

ARL-TR-787 July 1995

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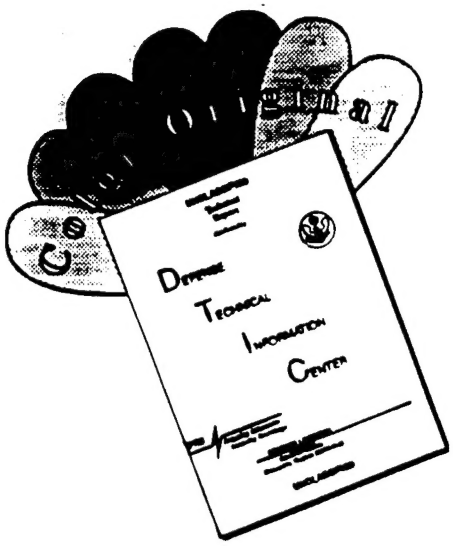

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The Modular Air-System Vulnerability Estimation Network (MAVEN) is a stochastic, pointburst model for all classes of air targets to include fixed- and rotary-wing aircraft and missiles. MAVEN is an approximation method under the Modular UNIX-based Vulnerability Estimation Suite (MUVES) and follows the Ballistic Vulnerability/Lethality Division (BVLD) Vulnerability/Lethality (V/L) process structure. MAVEN is intended to be used during all phases of the acquisition life cycle, from research and development through test and evaluation and fielding. The purpose of this report is to describe the initial version of MAVEN which models armor-piercing (AP) and armor-piercing incendiary (API) munitions.

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1. Introduction

The Modular Air-system Vulnerability Estimation Network (MAVEN) is a stochastic, point-burst model for all classes of air targets to include fixed- and rotary-wing aircraft and missiles. MAVEN is an approximation method under the Modular UNIX[1]-based Vulnerability Estimation Suite (MUVES) (Hanes et al. 1991 and Murray, Moss, and Coates 1994) and follows the Ballistic Vulnerability/Lethality Division (BVLD) vulnerability/lethality (V/L) process structure (see section 2.1 for a full description).

MAVEN is intended to be used during all phases of the acquisition life cycle, from research and development through test and evaluation and fielding (Roach 1994). The MAVEN project began in 1993 as an internal BVLD development project and may become the basis for the Advanced Joint Effectiveness Model (AJEM), a new air-system V/L model being jointly developed by the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME), and the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS).

The purpose of this report is to describe the initial version of MAVEN which models armor-piercing (AP) and armor-piercing incendiary (API) munitions. The penetration algorithms for this class of threat are based on the JTCG/ME Penetration Equations Handbook for Kinetic Energy Penetrators (JTCG/ME 1985). Before MAVEN is discussed, some background material is presented on the V/L process structure and MUVES.

2. Overview

2.1 Vulnerability/Lethality Process Structure

The BVLD V/L process structure is a mathematical and conceptual framework for thinking about V/L problems (Deitz and Ozolins 1989; Klopcic, Starks, and Walbert 1992; Walbert, Roach, and Burdeshaw 1993). This framework, also called the V/L taxonomy, can be thought of as a series of distinct levels of information through which analyses pass, as shown in Figure 1, and mappings between those levels. For a formal mathematical explanation of the V/L taxonomy, see the report by Walbert (1994). Level 0 is not formally part of the V/L taxonomy but is shown here for illustrative purposes only. The V/L part of the problem traditionally starts at Level 1.

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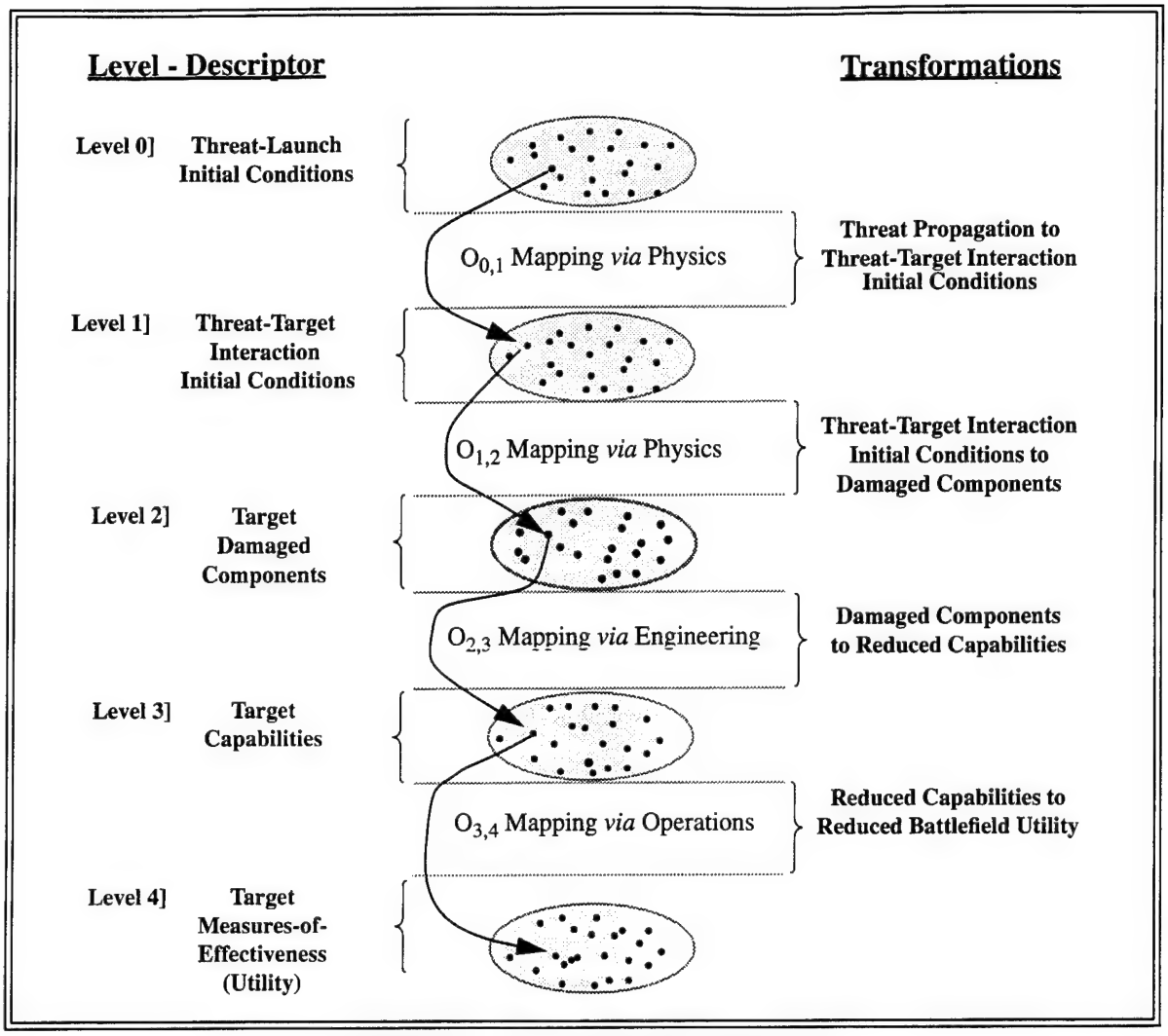

FIGURE 1. V/L process structure.

Level 1 represents all possible combinations of target-threat interaction initial conditions. Each point in the space represents a unique combination of these initial conditions. Fundamentally, the mapping from Level 1 to Level 2 ($O_{1,2}$) deals with physics such as penetration algorithms, fracture mechanics, etc. The result of this mapping is a list of damaged components. Level 2 represents the set of all possible combinations of damaged components, each combination represented by a point in the space. The mapping from Level 2 to Level 3 ($O_{2,3}$) primarily involves engineering with the result being a set of target residual capabilities. Each point in level 3 represents a unique combination of capabilities. These residual capabilities will have different effects on the target's combat utility depending on the mission and scenario and are determined via the $O_{3,4}$ mapping. The target's combat utility can be found by various operations research techniques such as force-on-force models and com-

bat simulations. Most importantly, at all levels, the results will be measurable and/or observable.

2.2 The Modular UNIX-Based Vulnerability Estimation Suite (MUVES)

Simulation models have been used in BVLD for performing V/L studies for over 30 years. These models have changed continuously as methodologies and algorithms have been developed or enhanced. These codes evolved individually and created a substantial support burden and configuration control problem. In 1985, BVLD initiated the MUVES project. Some goals of this project are:

- Use Ballistic Research Laboratory[2]-Computer Aided Design (BRL-CAD) Multi-device Graphics Editor (MGED) (Muuss 1991a) and ray-tracing libraries for solid modeling and target interrogation (Muuss 1991b)
- Minimize code redundancy
- Control code design and maintenance
- Facilitate extension of the production code for:
  - New situations
  - New analysis methods
  - Experimental applications
- Provide a modeling environment for developing new approximation methods.

MUVES can be thought of as a modeling environment within which approximation methods are developed and implemented (see Figure 2). An approximation method is roughly equivalent to what was considered a stand-alone model before MUVES. For example, it contains the collection of mathematical models and equations, assumptions, simplifications, and empirical data used to represent the physical process of the threat interacting with the target.

Figure 3 shows the top-level flow diagram for MUVES. There are three main parts of MUVES: the user interface, the vulnerability estimator, and the ray-tracer. The only part with which the analyst interacts directly is the user interface. Through this interface, the analyst can specify the parameters for a run and/or may perform file or project management functions. When setting up a run, the parameters for that run are stored in a file called a session file. This session file is stored as part of the audit trail of the analysis.

2. On 30 September 1992, the U.S. Army Ballistic Research Laboratory (BRL) was deactivated and subsequently became part of the U.S. Army Research Laboratory (ARL) on 1 October 1992.

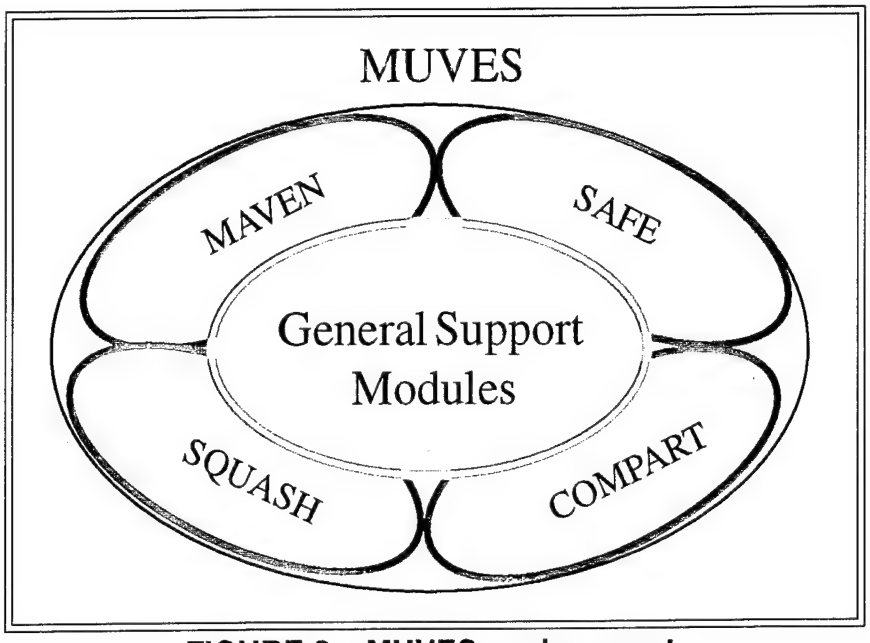

FIGURE 2. MUVES environment.

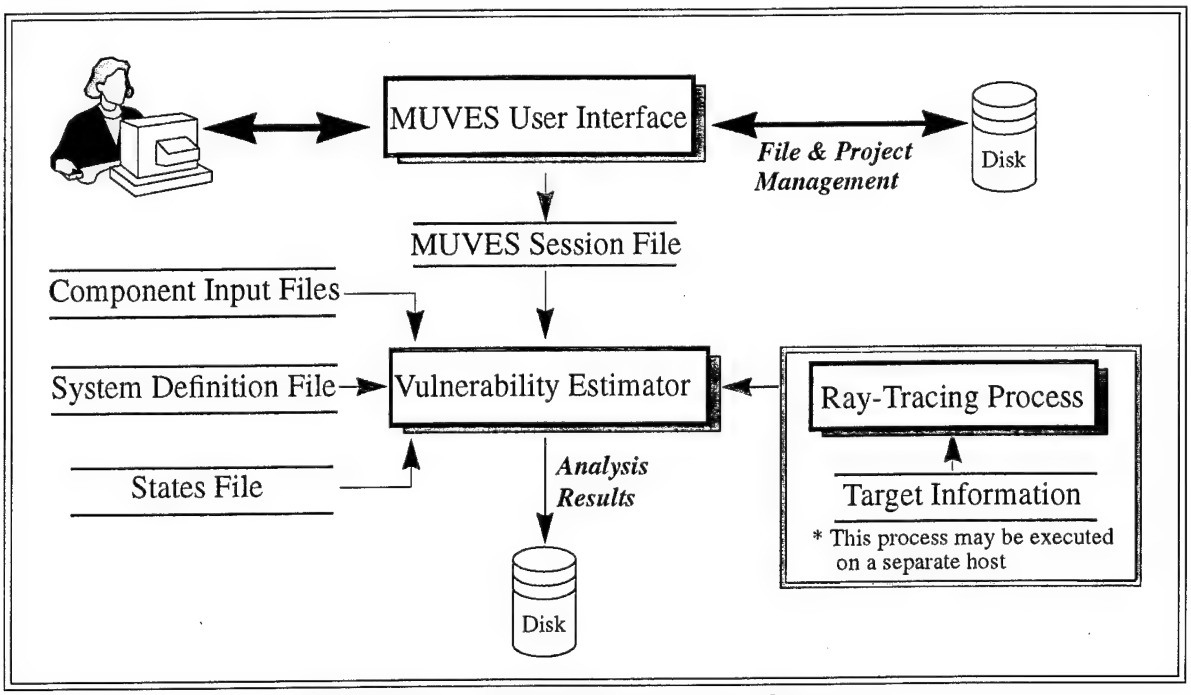

FIGURE 3. MUVES top-level diagram.

The session file is then used as input to the vulnerability estimator. Once this analysis is started, the analyst may then return to preparing inputs, through the user interface, for subsequent runs. The vulnerability estimator initiates a separate ray-tracing process to get the ray-trace information. The ray-tracing process may be run on the same machine as the user interface and the vulnerability estimator or on a separate host. This

allows the most compute-intensive part of the analysis to be run on a bigger, more powerful machine.

2.3 Consolidation of Models Under MUVES

There is currently a division-wide effort to consolidate all BVLD V/L models under the MUVES environment. This includes models for ground and air targets, and direct and indirect fire weapon systems. Likewise, MAVEN may ultimately replace a variety of air-system V/L models, such as the Computation Of Vulnerable Areas and Repair Times (COVART) (JTCG/ME Undated), which is used for AP munitions and single fragments. Others modules which eventually will be included are for blast and fragment munitions, potentially replacing the Personal Computer Assisted Vulnerability Assessment Methodology (PCAVAM) (Mayerhoffer and Douglass 1989), HEVART (Burk et al. 1987), and HEIVAM (ASI Systems Int. 1988).

The hit-to-kill modules in MAVEN will supplement PEELS and the LEGS family of codes (MLEGS, RLEGS, etc.) making use of the Tate cratering model (Frank and Zook 1991).

2.4 MUVES Terminology

In order to make clearer the description of AP and API modeling in section 3, some common MUVES terms are defined here. This section is a subset of the glossary in the MUVES Analyst's Guide.

- ***component trace*** - A component trace is the geometric information calculated for a single component during the course of a ray-trace through the target. Depending on the needs of the approximation method, it may contain entry and exit points, normal vectors, and curvature information.
- ***damage packet*** - A data structure which defines the type of damage done to a component and contains any parameters needed to describe the degree of damage (e.g., number of impacting fragments, hole diameter, deposited energy, etc.). Note that this data structure contains only the physical parameters of the damage and contains no information about the effects of the damage on the component's functionality.
- ***evaluation module*** (***EM***) - This is a module written by the approximation method developer to compute the functionality of a component based on the damage to that component during its interaction(s) with the threat(s).
- ***initial threat path*** - An initial threat path is a list of component traces from a ray-traced path through a target plus the parameters for the threat impacting the first component (before any interactions have occurred).

- ***interaction module*** (***IM***) - This is a module written by the approximation method developer to perform the calculations involved in the interaction of a single component with a threat. MUVES selects these functions based on the approximation method, the component category, and the threat type.
- ***ray-trace*** - Simulating the path of a projectile through a target. Used to ascertain the geometric information (line-of-sight and normal thickness, impactor/target obliquity) which is necessary for the penetration calculations.
- ***threat path*** - A list of component traces from a ray-traced path through a target, plus the parameters for a threat propagating along that path. This information is required to propagate a threat through a series of IMs in order to compute the damage to the target as a result of threat/component interactions; the subsequent components in a threat path may also change as a result of the interactions.

3. Armor-Piercing (AP) and Armor-Piercing Incendiary (API) Modeling

In this section, the abstraction-representation-implementation paradigm is used to describe the model for AP and API munitions (Barzel 1992). The abstraction is the set of key or salient ideas that capture the essence of the model. It is not necessarily mathematically precise. The representation is the formalization of the abstraction (mathematical model). It can be edited, copied, analyzed, debated, etc. The representation consists of two parts: the $O_{1,2}$ mapping and the $O_{2,3}$ mapping; these two parts are discussed in separate sections. The implementation expands or carries out the representation in some fashion. For MAVEN, it is the creation of the computer software that will be used by the analyst.

3.1 The Abstraction

The abstraction for AP/API is as follows: model the physical interaction between an AP or API munition against fixed- and rotary-wing aircraft and missiles; determine the effect of the damage on each component's ability to function; determine the residual capabilities of the target.

3.2 The Representation

3.2.1 Threat Information

For the JTCG/ME penetration equations, there are a number of parameters needed to fully describe an AP munition which fall into four basic categories: projectile dimensions, material properties, functional capacity, and state of motion. One assumption of the JTCG/ME penetration equations is that all AP projectiles have a cone-shaped nose.

The projectile description consists of the primary dimensions of length and diameter, as shown in Figure 4, and the parameters that describe the

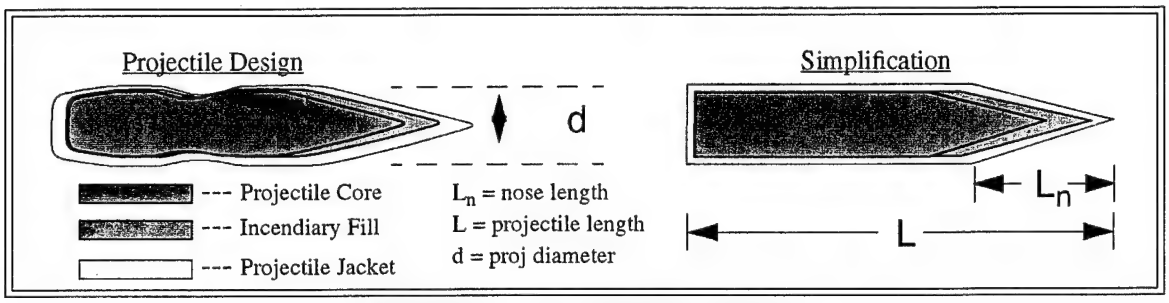

FIGURE 4. Projectile design.

shape: cone angle, ogive radius, and nose length. These parameters are required for both the overall projectile and the projectile core. Also required are the jacket thickness and the weights of the full projectile and core, as well as material properties: elastic modulus, tensile strength, density, Brinell hardness, and speed of sound in the material, which pertain to the core.

Incendiary functioning capability, which indicates whether the round still has incendiary capability, is either true or false. There are four functioning ratios required for the JTCG/ME incendiary functioning algorithms: complete, partial, delayed, and slow burn. The equations for incendiary functioning also require nine empirical constants as described in the JTCG/ME handbook (JTCG/ME 1985), six for the delta q and three for q_a.

The state of motion of the projectile is described by the velocity, yaw angle, and yaw factor. In order to correctly represent the interaction of the projectile and the target, the target's velocity must also be input. Figure 5 is an example of an initial threat file.

```
# Threat        Threat
# Name          Type
# ----          -------
threat2         AntiAirArmorPiercingProjectile
{               projectile_diameter = 0.90                  # inches
                projectile_length = 3.91                    # inches
                projectile_nose_length = 0.80               # inches
                projectile_weight = 2968                    # grains
                projectile_tip_diameter = 0.05              # inches
                core_diameter = 0.90                        # inches
                core_length = 2.55                          # inches
                core_nose_length = 0.80                     # inches
                core_weight = 2550.                         # grains
                core_elastic_modulus = 211.E9               # Pascals
                core_tensile_strength = 1.055E9             # Pascals
                core_density = 1980.0                       # grains/cu. in.
                core_sound_speed = 16586.0                  # feet/second
                brinell_hardness = 300.0                    # feet/second
                jacket_thickness =.05                       # inches
                velocity = 3000.0                           # feet/second
                yaw_angle = 0.0                             # radiams
                yaw_factor = 1.0                            # between 0 and 1.
                target_speed = 0.0                          # feet/second
                q1 = 0.0                                    # delta q constant
                q2 = 0.0                                    # delta q constant
                q3 = 0.0                                    # delta q constant
                q4 = 0.0                                    # delta q constant
                q5 = 0.0                                    # delta q constant
                kf2 = 0.0                                   # delta q constant
                qf0 = 2.07                                  # qa constant
                qf1 = 1.59                                  # qa constant
                kf = -.702                                  # qa constant
                incendiary = true                           #
                complete_function_ratio = 1.0               #
                partial_function_ratio = 0.5                #
                slow_burn_ratio = 0.5                       #
                delayed_function_ratio = 0.5                #
                deflect = false                             #
}
```

FIGURE 5. Initial threat file.

Another input file required to characterize the threat contains the probabilities of incendiary functioning for the various functioning modes: complete, delayed, slow burn, and partial. The probabilities are functions of the incendiary functioning parameters, q_{tn} and q_a, which are described in the JTCG/ME handbook on pages 23 to 30.

3.2.2 *Target Information*

There are a variety of target-related input files. The first file is the *target description*. The only geometry currently supported by MUVES is BRL-CAD (Muuss 1991a). The second file required is called the *region map file*. It associates the region identification numbers with names which are determined by the analyst. This allows the analyst to group the regions into larger entities (i.e., components). These names from the region map file are then used in all the other component-related input files. Third, the *component category map file* is used to group components. Each group in the component category map file corresponds to a unique IM in MUVES. In other words, the physical interaction of the threat with the components in a particular component category is handled with the same IM. The next component-related input file is the *component properties*

file. This file contains all pertinent component properties necessary for the algorithms being used in MAVEN such as density, Brinell hardness number, bulk modulus, etc. Lastly, the probability of component dysfunction given a hit ($P_{cd/h}$) is required for each component. These probabilities are contained in a file called the *component $P_{cd/h}$ file* and are based on the impactor's mass and velocity.

3.2.3 $O_{1,2}$ Mapping

The $O_{1,2}$ mapping takes place in two steps (see Figure 6). First, the physical interactions between the impactor and the target components are simulated for each component on the threat path. The initial threat parameters and the geometry information (component trace) for the first component on the threat path are passed to the IM for that threat and component category combination. Since the damage criterion for AP projectiles against components is a probability of component dysfunction given a hit ($P_{cd/h}$) as a function of impactor mass and velocity, the impactor's mass and velocity (if the component is critical) are written to a damage packet.

As stated earlier, the mathematical model used to represent the penetration of the impactor through the target is derived from the JTCG/ME handbook (JTCG/ME 1985). Figure 7 shows the flowchart for the principal computation for AP and API projectiles. The algorithms and equations from this handbook apply to the AP and API munitions between 7.62 mm and 57 mm. Target components are relatively thin, and the majority are made primarily from aluminum alloys or low-strength steels. Target components are approximated as plates, even though they may be curved because of the intense localization of the forces from the impactor.

The first step is to calculate the presented area of the projectile. Then a decision is made on the modes of perforation (either piercing or plugging) or ricochet. A different set of equations is used to calculate the changes in the state of motion for each of the three choices. Next, a decision is made on the mode of impactor failure to include core breakup and incendiary functioning.

The JTCG/ME penetration equations are used to calculate the residual mass, velocity, and obliquity of the impactor. In the initial version of MAVEN, the residual obliquity information is not used. In future versions, it will be an analyst's option to generate a new threat path using the residual obliquity (the penetration algorithms are discussed in greater detail later in this section). The residual threat parameters and the geometric information of the next component on the threat path are then passed on to the IM for that threat and component category combination,

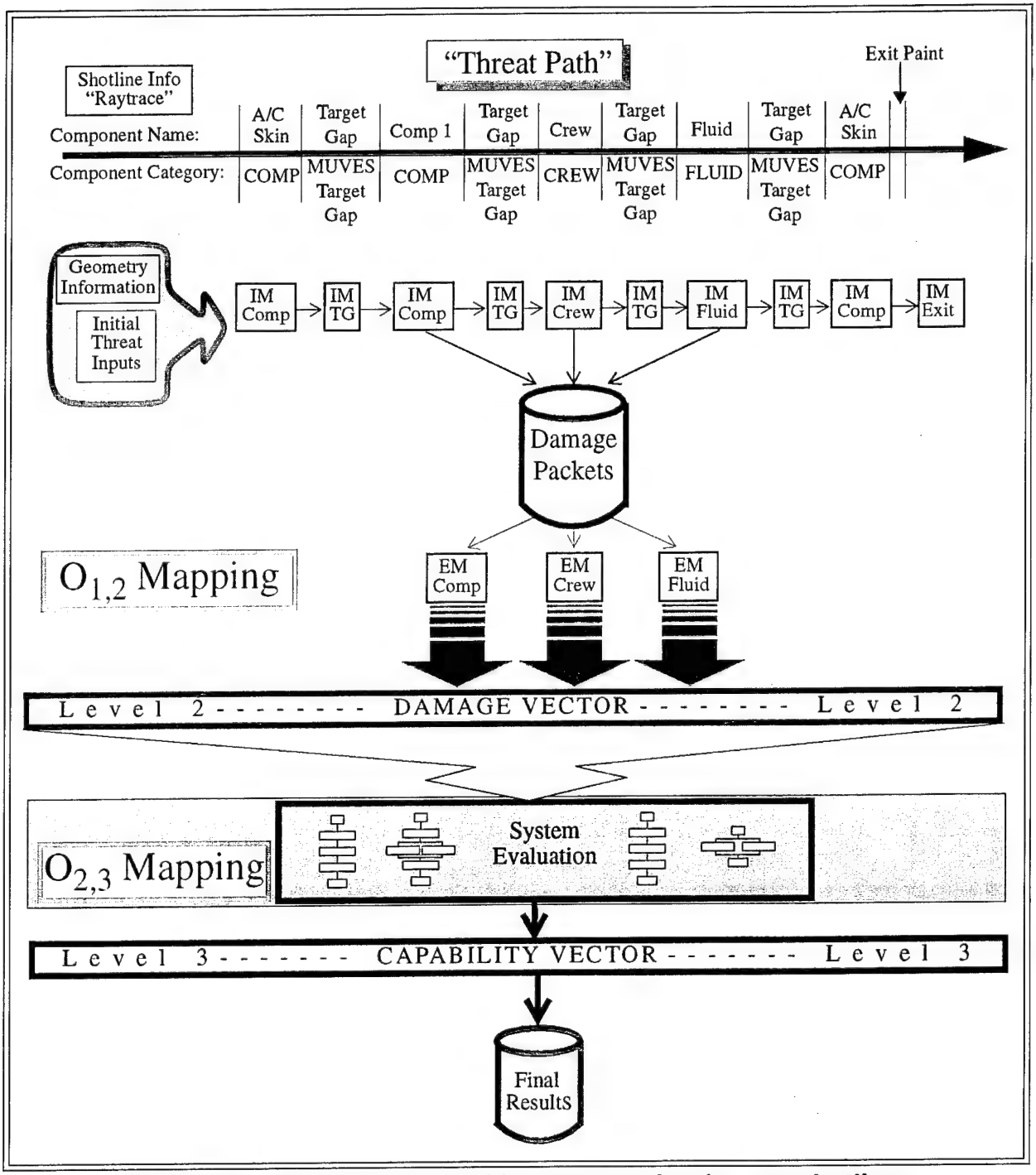

FIGURE 6. MUVES vulnerability computation for one shotline.

where damage is computed, and the damage packet is written for that component. This process is repeated until the impactor exits the target or its velocity or mass is reduced to zero.

Once all target-impactor interactions are processed, the damage packets that were produced are sorted by component. All of the damage packets

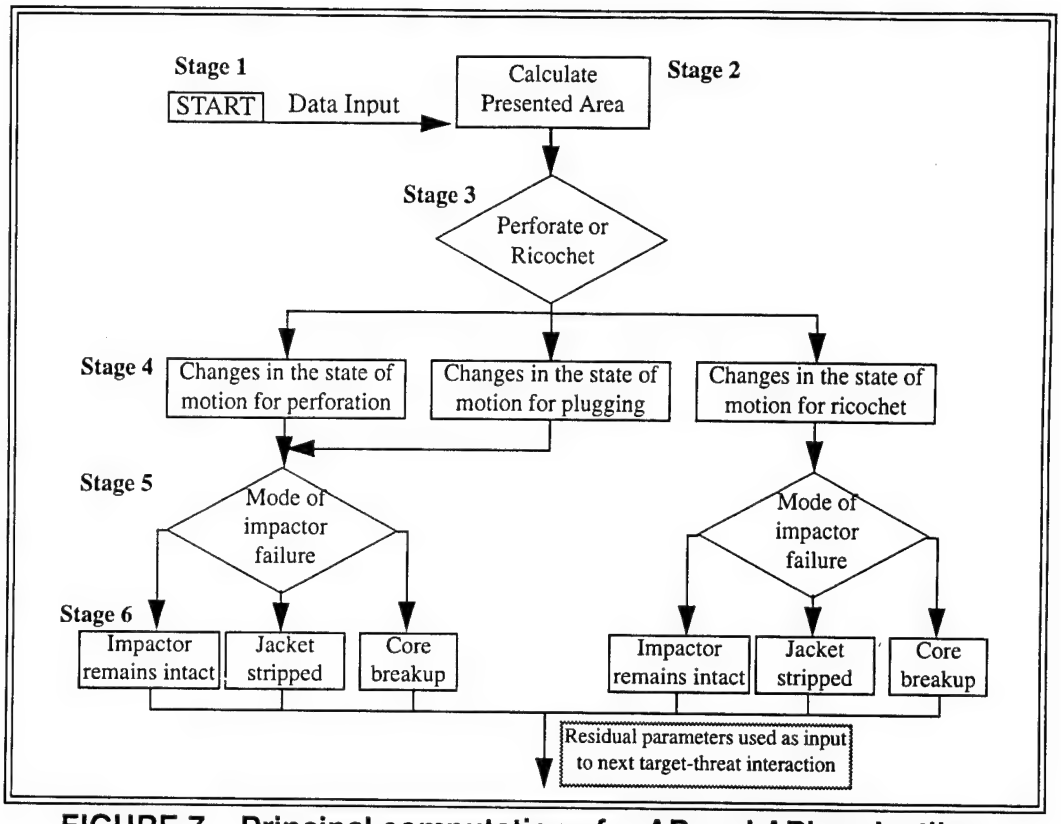

FIGURE 7. Principal computations for AP and API projectiles.

for one component are then passed to the EM for that component. The EM then finishes the $O_{1,2}$ mapping by taking the damage information, mass, and velocity of the impactor and looking up the $P_{cd/h}$ for that component. A random draw is then performed, and the component is determined to be either functional or nonfunctional. That Boolean value is then stored in the damage vector.

The result of the $O_{1,2}$ mapping is a damage vector. The damage vector is a list of the functional state of each critical component (i.e., they are either functional or nonfunctional). Since the fault trees in MAVEN are created using positive logic (see section 3.2.4), the damaged component information is also created using positive logic. Positive logic infers that a fully functional component is represented by a 1 and a completely dysfunctional component is represented by a 0. MAVEN currently produces only Boolean component information.

3.2.4 *$O_{2,3}$ Mapping*

The $O_{2,3}$ mapping, which converts damaged component information to residual capabilities, is done using fault trees. This is commonly referred to as the Degraded States Vulnerability Methodology (DSVM) (Abell, Roach, Starks 1989). Figure 8 shows an example of series, parallel and combination fault trees. For a series fault tree, all elements of the tree

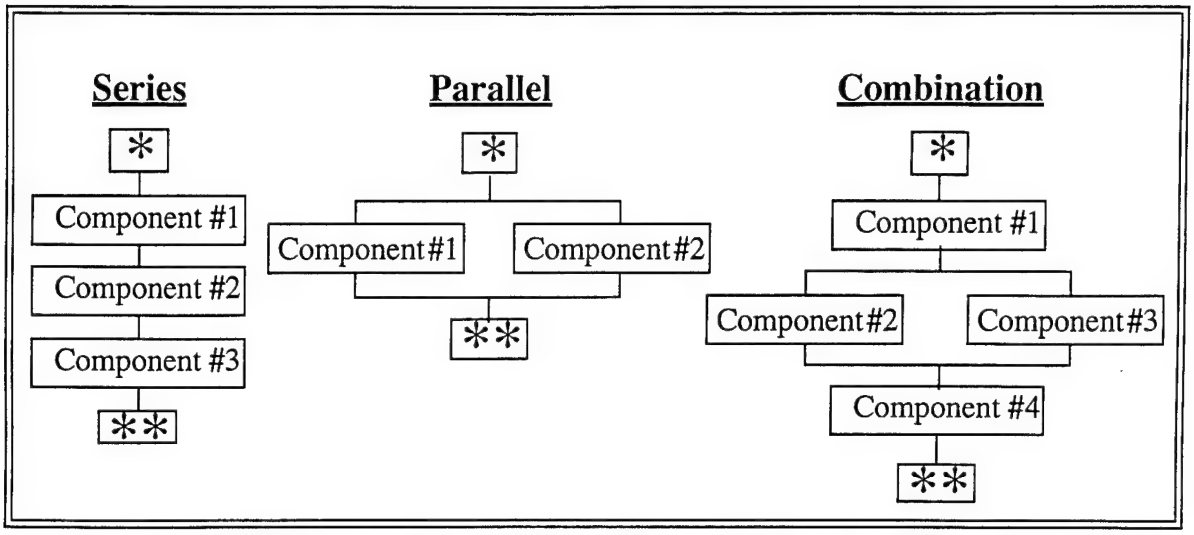

FIGURE 8. Series, parallel, and combination fault trees.

must be functional in order for the capability represented by the tree to be available. In other words, the series relationship is translated into a Boolean "AND". For the parallel fault tree, if either component is functional, the capability represented by that fault tree is available (i.e., a Boolean "OR" relationship). The third type of fault tree is a combination of the two.

3.2.4.1 System Definition File

The system definition file (*sysdef*) contains the fault trees for all of the systems of interest to the analyst. MUVES has a unique built-in language for specifying fault trees called the system definition language. Figure 9 shows examples of the three types of fault trees discussed in the previous section.

3.2.4.2 States File

The *states* file specifies the output metric for a target to be written to the final results file after it has been damaged by a threat. A states file consists of one or more state vectors. Each state vector contains the name and type of vector followed by one or more vector elements. The vector elements may be either component names, as defined in the region map file, or system names as defined in the system definition file. One or more of the state vectors defined in the states file may be selected by the analyst when running MUVES. It is most useful to the analyst to create a states file containing all of the state vectors that are expected to be needed. Then when conducting an analysis it is simply a matter of selecting the appropriate state vectors from the states file. Figure 10 is an example states file.

Series

```
#
# Definition for Intermediate Gearbox
#
"Intermediate Gearbox" =
                igb_input_drive_flange
                & igb_input_bevel_pinion_gear_shaft
                & igb_input_and_output_gear_shaft_inner_brngs
                & ibg_output_bevel_gear_shaft
                & ibg_output_drive_flange_shaft
                & ibg_input_and_output_gear_shaft_outer_brngs
                & igb_housing
                & igb_fan_gearbox
```

Parallel

```
#
# Definition for M4
#
M4 =
        (
                lt_engine_inlet_front_frame
                | rt_engine_inlet_front_frame
        )
```

Combination

```
#
# Definition for Main Transmission Lube
#
"Main Transmission Lube" =
        main_transmission_gear_case
        & (
                no_1_oil_filter
                | no_2_oil_filter
        )
        & xmsn_oil_sumps_no_1_and_no_2
```

FIGURE 9. System definitions for series, parallel, and combination fault trees.

3.2.4.3 Damage Evaluation Selection (DES) File

The damage evaluation selection file is used by the analyst to specify the name of the EM desired to evaluate damage for each critical component. There should be one EM specified for each category of components from the component category map file. Figure 11 shows an example of a DES file.

3.3 The Implementation

The MUVES source code is organized into a variety of different packages where each package is designed to serve a certain need. For example, the Ray-Tracing (Rt) package contains all of the code related to performing ray tracing in MUVES. The software implementation of the MAVEN approximation method required additions to the existing MUVES code. These were additions to the Physical Interaction (Pi) package, the Threat package (Th) and the System Evaluation (Se) package. In the "methods" directory a "maven" directory was added which contains the IM and EM code and other utility functions for initializing data structures and initializing and terminating a MAVEN analysis.

```
#
# State Vector file for maven.
#
#
systems killed =
{
        lt_engine_agb,
        rt_engine_agb
}

mobility killed =
{
        ANY_MOBILITY,
        ALL_MOBILITY,
        M1,
        M2,
        M3,
        M4,
        M5,
        M6,
        M7,
        M8,
        M9,
        M10,
        M11,
        M12,
        M13,
        M14,
        M15,
        M16
}

operate killed =
{
        ANY_OPERATE,
        ALL_OPERATE,
        O1,
        O2,
        O3,
        O4,
        O5,
        O6,
        O8
}

communicate killed =
{
        ANY_COMMUNICATE,
        ALL_COMMUNICATE,
        C1,
        C2,
        C3
}
```

FIGURE 10. States file.

3.3.1 *Additions to the Physical Interaction (Pi) Package*

The code for doing penetration calculations along the shotline in MUVES is included in the Pi package. The JTCG/ME penetration equations were not previously part of MUVES. There is one main module, PiMeApPen, which controls the flow of calculations and is called from an IM, and a group of smaller modules which carry out specific calculations. Figure 12 is a structure chart which shows the hierarchy of these modules. PiGetPkts and PiGeomPkt get pointers to the threat packet and the geometry information, respectively. PiProjAp contains the equations for calculating the presented area of the projectile on the target component along the shotline. PiModeofPerf calculates the mode of perfora-

```
#
# Damage Evaluation Selection file for target
#
# Critical Component
# Category                        Evaluation Module function name
# --------                        -------------------------------
components                        aaapp_mass_velocity

# Future component categories shown below
# fluids                          aaapp_fluids
# dry_bay                         aaapp_fire
# crew                            aaapp_crew
```

FIGURE 11. Damage evaluation selection file.

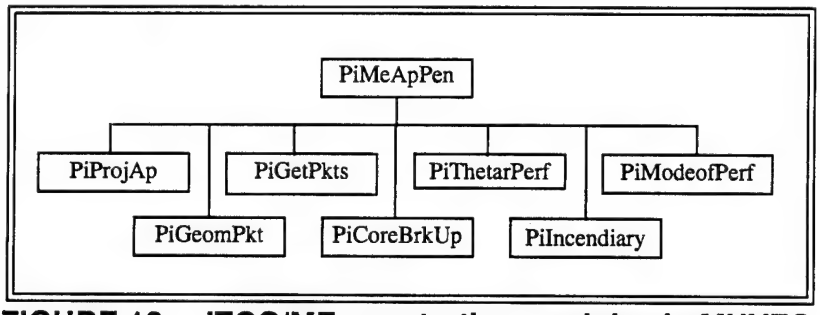

FIGURE 12. JTCG/ME penetration modules in MUVES.

tion, either piercing, plugging, or ricochet. PiThetarPerf calculates the residual obliquity after the impactor has perforated. PiCoreBrkUp performs the core breakup calculations, and PiIncendiary calculates the incendiary functioning probabilities.

3.3.2 *Additions to the Threat (Th) Package*

The threat information is contained in a data structure called the threat packet. The functions added to the Th package are used to initialize the threat packet, read the initial threat file, and write out information about the threat to the intermediate results file.

3.3.3 *Additions to the System Evaluation (Se) Package*

The traditional damage vectors and fault trees in MUVES are expressed using negative logic. It was decided that for MAVEN analyses, the fault trees would be expressed using positive logic. Therefore, the Se package was modified to allow production of damage vectors in terms of either positive or negative logic. This functionality was added specifically to support MAVEN, but can be utilized by other approximation methods as well.

3.3.4 *The Method-Specific (MAVEN) Directory*

This directory contains all method-specific code. The file maven.c contains all method initialization functions and some utility functions for initiating and terminating analyses. All of the IM and EM code is also contained in this directory. There are four IM's: AP vs. components, AP vs. target gap, flag threat vs. components or target gap, and any threat vs. exit paint. A flag threat is a fictitious threat which is propagated down the threat path after the real threat has ceased to penetrate.

3.3.5 *Verification of MAVEN*

To date, a limited verification has been conducted to ensure that the penetration calculations performed in MAVEN are working properly. This has involved modifying COVART 3.3 and MAVEN with many additional print statements to output the values of the intermediate calculations. The values from both codes were then compared. There are a number of deviations between the COVART code and the JTCG/ME handbook. This is because the last version of the handbook was published in 1985. Since that time the algorithms have evolved and several typographical errors in the handbook have been discovered and corrected. Therefore, the "state-of-the-art" in terms of the JTCG/ME penetration equations are reflected by the COVART source code. These deviations were confirmed by a COVART expert (Burk 1995). The penetration calculations in MAVEN were changed to agree with those in COVART, Version 3.3.

4. Future Development Efforts

There are a number of ongoing development efforts which will greatly increase the functionality of the MAVEN model and enable analysts to perform analyses on a wider range of threats. The next threats to be modeled will be high-explosive and high-explosive incendiary munitions. This will involve modeling both blast and fragments for internally bursting munitions. Also implemented will be a multiple fragments model (externally bursting munitions), a dry bay fire model developed by the U.S. Air Force, and a body-to-body methodology for modeling antiair munitions against tactical ballistic missiles.

4.1 High-Explosive (HE) and High-Explosive Incendiary (HEI) Modeling

There are currently two different methodologies being implemented into MAVEN to model HE and HEI munitions. The first is PCAVAM, which is a combination of manual and spreadsheet calculations. This model considers the combined effects of blast and fragment damage. For MAVEN, only the blast portion of PCAVAM is being used. For the frag-

ment modeling, the FATEPEN 2 (Yatteau, Zernow, and Recht 1991) methodologies will be used. FATEPEN 2 has already been reconfigured and rewritten in the C programming language for use in MAVEN.

4.2 Multiple Fragments

Multiple fragments from externally bursting munitions will be modeled in MAVEN. This work will take advantage of work done by the Logistical and Tactical Targets Branch (LTTB) of BVLD. This approximation method is called the Stochastic Analysis of Fragmenting Effects (SAFE) (Hunt, J.E. 1995). The fragment penetration will be modeled with FATEPEN 2.

4.3 Dry Bay Fire Modeling

The U.S. Air Force, through a contractor, has developed a dry bay fire model (Pascal, A.M. 1994) which calculates the probability of fire initiation and determines the temperature and pressure-time history within three dry bay regions. The model is physics based and very detailed.

4.4 Hit-to-Kill

BVLD is developing the capability to model the lethality of hit-to-kill interceptors. This methodology will use the Tate cratering methodology to simulate the physical interaction of the interceptor missile and the target. This model will differ from current missile lethality simulations in the following ways:

- Measurable/observable results
- Direct use of BRL-CAD target descriptions of both target and interceptor
- Stochastic modeling of physical mechanisms.

5. Conclusion

The Modular Air-system Vulnerability Estimation Network (MAVEN) is part of the Modular UNIX-based Vulnerability Estimation Suite (MUVES) and is a stochastic point-burst model for all classes of air targets to include fixed- and rotary-wing aircraft and missiles. It is to be used during all phases of the acquisition life cycle, from research and development through test and evaluation and fielding. Armor-piercing projectiles are currently the only threats modeled. However, high-explosive, fragmenting and hit-to-kill munitions are currently being added to MAVEN.

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